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IARIA

International Academy, Research, and Industry Association

Earth-Satellite Monitoring System for Storaged Grains

A work in progress

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CRIAR Space SYSTEMS

https://criar.space

Global Positioning:

Nationwide: Brazil, over 15 States

Worldwide: Portugal China

Project Partnership:

Embrapa

Empresa Brasileira de Pesquisa Agropecuária

The Problem

Grain Production in Brazil:
In 2024, the country is expected to have a record harvest of 300 million tons of soybeans, corn, cotton, rice, and wheat. This has increased year-by-year!

Brazil has nowhere to store the SUPER crops, as it lacks storage infrastructure with quality control of the stored grain.

- This record production would cause a storage deficit of more than 100 million tons

The Solution

Bag silos are an economically inexpensive solution, but they lack control and monitoring of the quality of stored grains, as grains are often stored in uncontrolled areas.

However, to solve this deficiency, we monitor the stored grains, indicating possible spoilage and storage problems, using sensors connected to the internet, through a Proper and Exclusive Satellite, alerting about problems via cell phone app and administrative website.

e-SILOBAG

Earth-Satellite Monitoring System for Storaged Grains

Project Description

Agribusiness is an economic segment with the greatest evolution in generating wealth.

Source: Storagegrain

With a storage deficit per harvest, **silo bags** became an alternative.

GENERAL INFORMATION:

- ✓ Food production increases year by year;
- ✓ One of the crucial problems is related to grain storage;
- ✓ The availability of grain storage is lower than the total of grain produced;
- ✓ Producers are forced to promptly sell production that could not be stored;
- ✓ Some companies sell **SILO BAGS** as a fast way to overcome this situation.

DIFFICULTYS:

- ✓ Grains stored in silos are susceptible to insect infestation and fungal growth;
- ✓ Loss of part or even the entire stock, depending on initial storage conditions;
- ✓ Requires data transmission in areas that lack cellular network coverage.

OBJECTIVES:

- ✓ **This project proposes sensor monitoring post-harvest variables to detect or even forecast potential risks to the quality of the stored product.**
- ✓ **Reduce the risk of damage to stored grains considering that different storage environments have characteristics that increase types of risk.**
- ✓ **It is estimated that technology can reduce losses from 10-25% to 1-3%**

Partnership between Academia and Industry

This demand was embraced by the company **CRIAR Space Systems** which is, together with **Embrapa**, working on solutions such as installing **SILO BAGS** by monitoring physical and chemical variables in those silos to automatically produce alert signals.

These signals can indicate the presence of contamination in the silos due to local fermentation, or due to the presence of high/low bulk moisture and temperature, for instance.

Another **CRIAR** feature is the development of communication antennas for satellite signals with the purpose of further launching a private satellite dedicated to monitoring all farms covered by this service.

The scope of this work in progress is to show how this is being planned and applied.

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Embrapa is an innovation-driven company that focuses on the generation of knowledge and technology for Brazilian agriculture

About Silo Bags

SILO BAG is a grain storage system made with a multi-layered, tube-shaped plastic bag of varying length and diameter (most typically 60 m long and 2.7 m in diameter), with a holding capacity of about 200 metric tons (T) of corn, wheat or soybeans.

The plastic cover is usually white on the outside, black on the inside and it is used for storing different grains and by-products during a variable period of time, from a few weeks to several months.

Example of silo bags on the farm

Source: IpesaSilo

With a storage deficit per harvest, silo bags became an alternative.

Source: BrasilAgro

Set of silo bags

Source: Agrolink

Machinery designed to pocket grains (grain bagger).

Source: FarmProgress

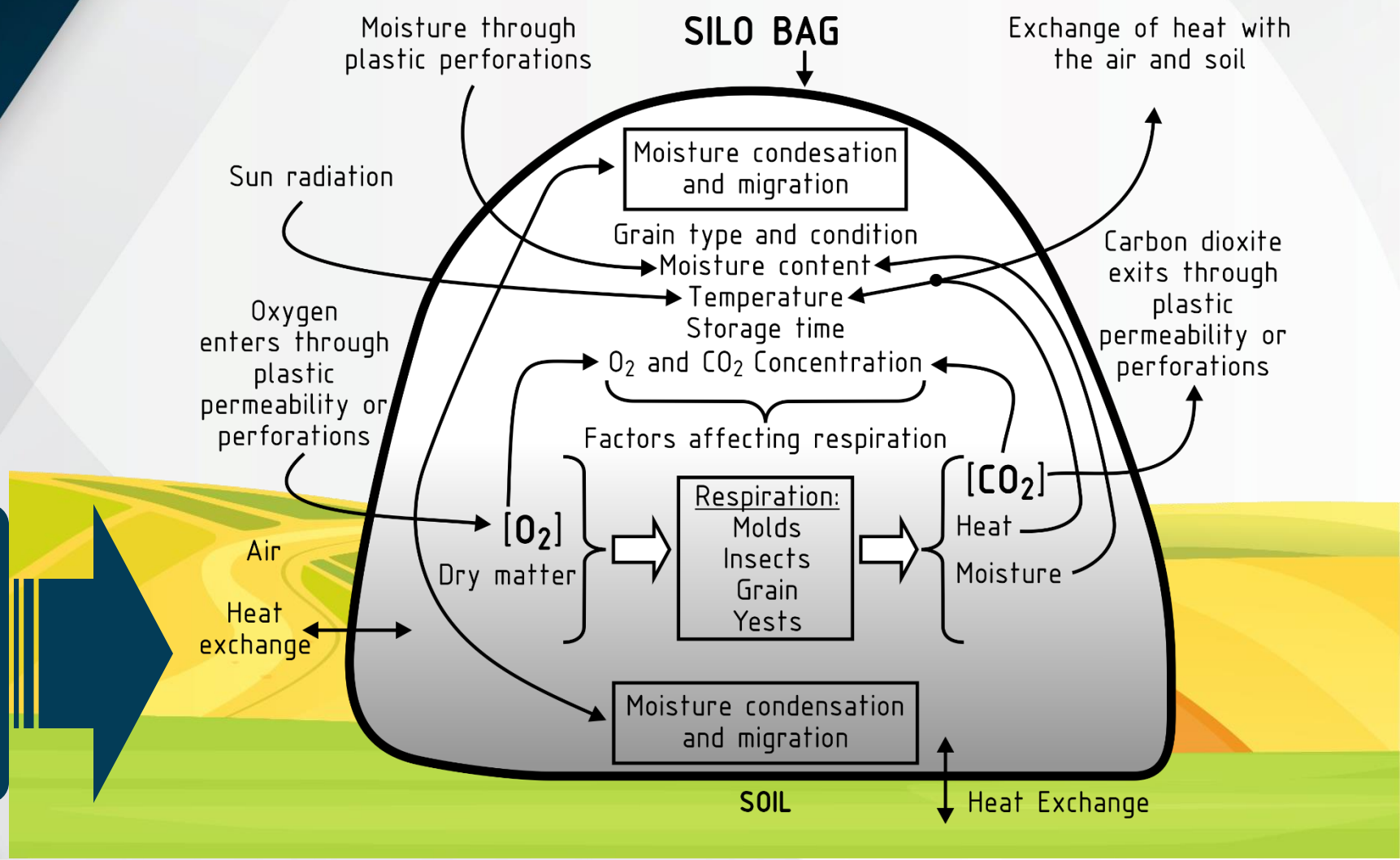
Factors affecting the grain ecosystem

Environmental Influences:
Temperature, CO_2, O_2, and humidity levels;

Temperature Fluctuations:
The impact of temperature cycles on moisture migration and subsequent grain quality losses;

Mycotoxin Formation:
The underlying mechanisms of mycotoxin contamination;

Insect Infestation:
The incidence, dynamics, and impact of insect presence on grain quality.



Sectional diagram of a silo bag, illustrating the main factors that affect the grain ecosystem, the relationship between them and the external environment.

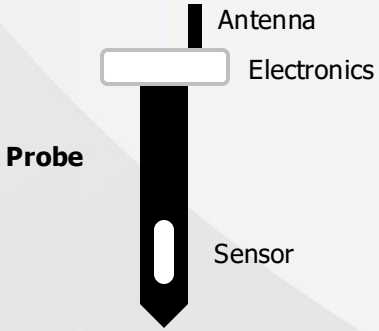
Main Project Concepts

This project proposes monitoring post-harvest variables to detect or even forecast potential risks to the quality of the stored product.

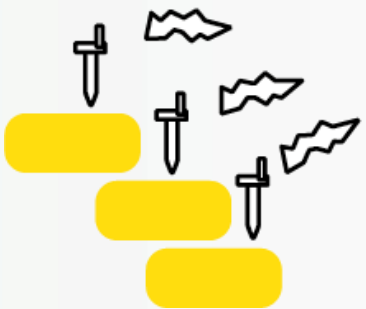
In silos exposed to the environment, the intergranular temperature and the relative humidity of the air inside the silo are two basic observable variables of the internal ecosystem of the silo, but they are insufficient to detect signs of deterioration in the quality of the stored grains.

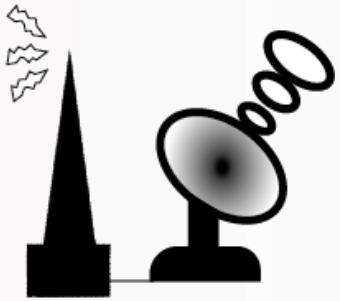
One of the working hypotheses of this project is that specific variables must be added to the intragranular temperature and the relative humidity of the air inside the silo according to the characteristics of the stored product.

Monitoring storage systems becomes a viable alternative to reduce the risk of most types of accidents.



Probe schematic. The probe is composed of sensors, conditioning electronics, and antenna.

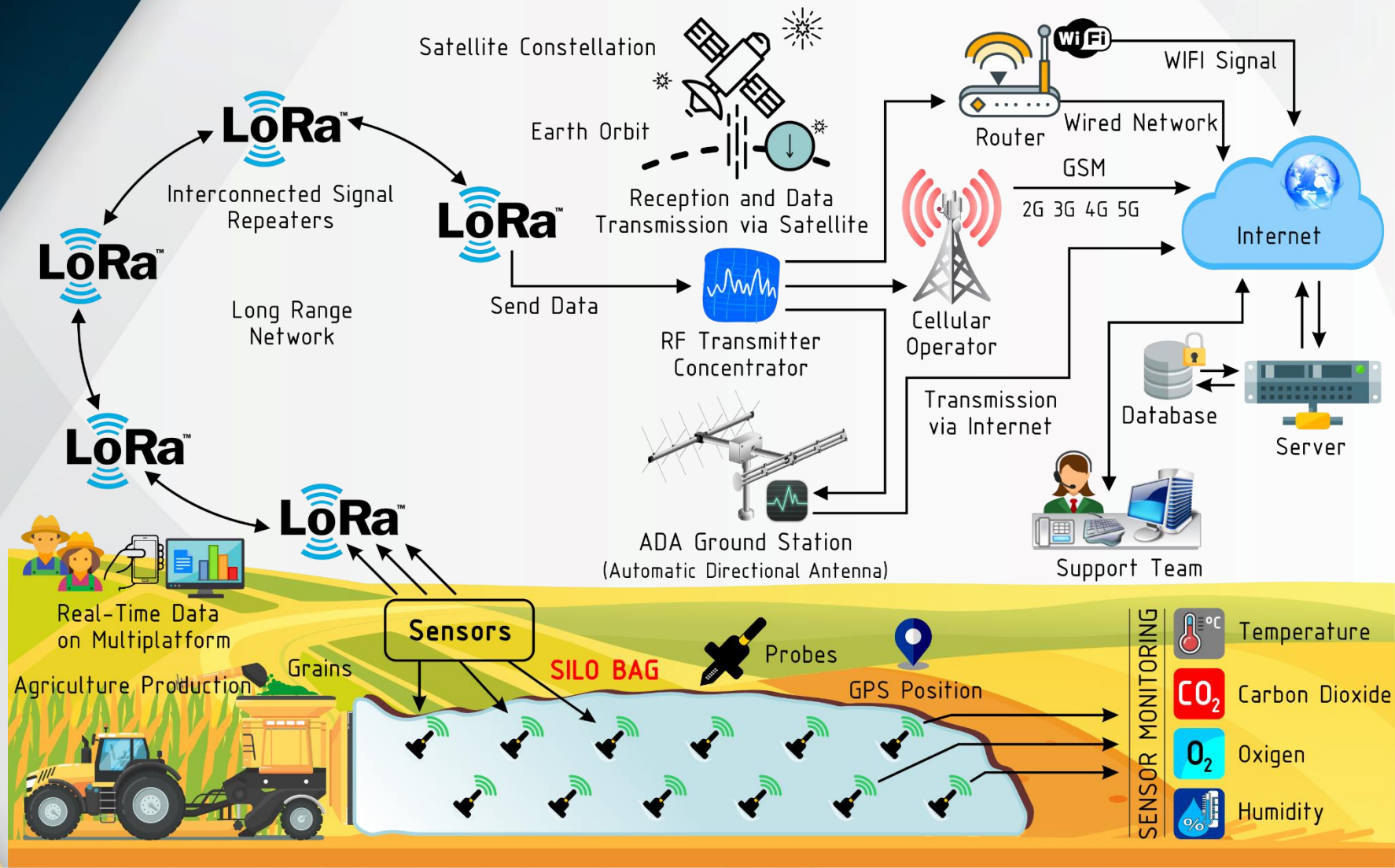




Ground communication network is formed by probes installed in the silos, a hub (data concentrator) coupled to a ground station that transmits the signal to the satellite.

System Overview

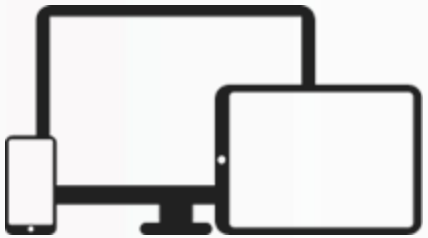
- ✓ Smart sensors (IoT);
- ✓ Expandable autonomous network;
- ✓ Configurable parameters;
- ✓ Online monitoring;
- ✓ GPS positioning;
- ✓ Remote management;
- ✓ Statistical analyses;
- ✓ Data security;
- ✓ Higher quality;
- ✓ Low cost.



Monitoring Applications

Grains Stored Under Control

- Useful information related to food safety;
- Collection and management of relevant information;
- Notify consumers about relevant data of the production process;
- Real-time notification about the conditions of grains stored in silo bags;
- Instant alerts when any of the parameters are out the expected ranges;
- History, trends and statistical analyzes to meet the needs of each producer.



Resource Savings

Minimizing Storage Losses

Intelligent monitoring allows to take action before the product is lost;

Optimizing Compost Ripening Time

Precise analysis of the ripening point avoids product losses in the curing process;

Avoid Product Devaluation

Delivery within the required quality standards avoids batch rejection.

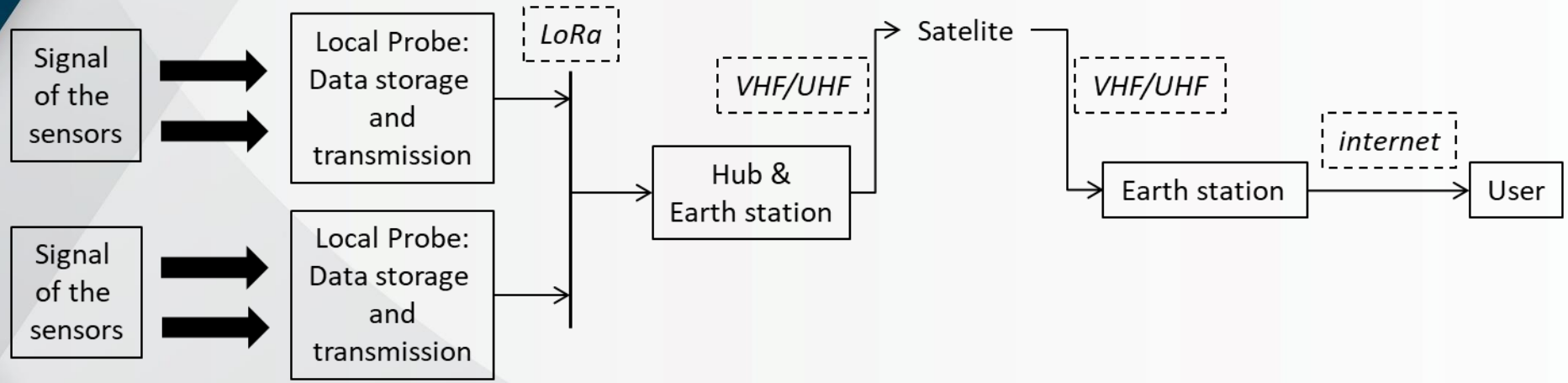
Working on Solutions

Architecture Flowchart for Terrestrial Grain Monitoring

Probes with sensors for CO_2, O_2, temperature, and humidity, along with signal conditioning electronics, a battery, and a LoRa radio, are installed in storage units based on volume and conditions.

Probes periodically transmit data to an Ground Station, which has a dedicated receiver with a radio antenna, signal conditioning electronics, a satellite antenna positioning system, and VHF/UHF transmission equipment.

Protected by IP65 standards, the system sends data to a Low Earth Orbit (LEO) satellite, which then retransmits it to a second Ground Station responsible to send data via internet to a database and finally to the user in a suitable format.



Data obtained by the probes are sent by radio to a first Earth Station, which then transmits it to the satellite. After amplification, the signal is retransmitted to a second Earth station and to the silo manager.

Sensing and Ground Communication

CRIAR Space Systems manufactures its own measurement devices from commercial transducers. The process includes the development of the signal conditioner and calibration.

Periodically, the probes send the reading packet of a given moment in time to a data concentrator located in a suitable location that can be several kilometers away.

JLCP (communication protocol) general characteristics:

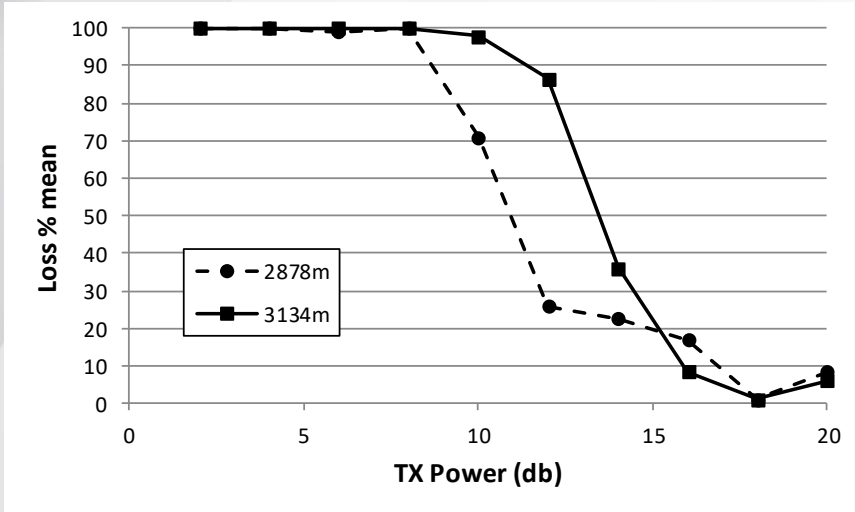
- ✓ The message is divided into packets;
- ✓ Each packet sent requires confirmation from the receiver;
- ✓ The transmitter moves to the next packet only after receiving confirmation;
- ✓ If no confirmation is received within timeout period transmitter resends packet;
- ✓ Exceeding resend attempts the session is terminated due to a connection error;
- ✓ Data integrity is ensured with a Cyclic Redundancy Check (CRC);
- ✓ Packet completeness is verified by parsing the received string into JsonArray;
- ✓ Redundant packets are managed by route locking and sequential filtering;
- ✓ Payload encryption must be handled by the sender and receiver.

Experiment Results

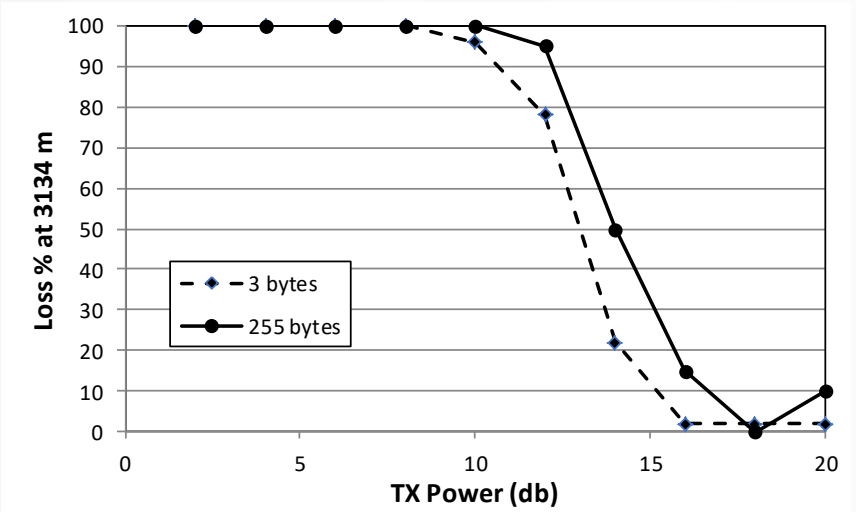
The tested system was capable of processing 3-byte and 255-byte data packets over distances of up to 3134m, with a TX power of 18db.

On the time line, **the 1st event was a test of distance.** A 3-byte data packet was transmitted over different distances and radio power levels meaning information loss across the two longest tested distances and also indicates that at a transmission power of 18dB, there is minimal signal loss.

The **2nd test was conducted to evaluate the transmission** of 3-byte and 255-byte data packets over a distance of 3134 meters at various transmission powers showing that the minimal signal loss for a 3-byte payload was 16dB, while the minimal loss for a 255-byte payload was 18dB.



Percentage Packet Loss (3-Byte and 255-Byte Packets) over a 3134-Meter Transmission at Varying Radio Transmit Powers



Payload mean loss at 2,878 meters and 3,134 meters transmission distances with different radio transmission powers

Conclusions

Storage Duration: Corn can be stored in a silo-bag for up to 24 months under suitable conditions;

Metabolism: Oxygen consumption keeps grains at a low metabolism;

Humidity Risks: High humidity can cause fungal and bacterial infestations fermentation begins after oxygen is consumed;

Capacity and Value: A 60m x 2.5m silo can store 220 tons of corn, worth ~USD 47K;

Monitoring Solution: Proposed monitoring via satellite data transmission to prevent loss;

Technology: Data transmission via satellite is suitable even for remote areas and the proposal solution includes a terrestrial transmission stage, uplink, downlink and another terrestrial stage;

Development: Team working on low-orbit satellite design and terrestrial transmission system. Current range over 3 km, with aims to increase;

Challenges: Power source limitations, sensor and electronics robustness, and data integrity;

Focus Areas: Earth Station instrumentation, sensor technology, and data transmission;

Business Challenge: Maintaining an attractive final product price.

Expectations

Strategic Partnerships: Opportunity to forge new partnerships with the University, which will expand capabilities and reach, allowing the delivery of innovative solutions;

Identify New Suppliers: Especially with those distributors, dealers and manufacturers of high-precision sensors and electronic components to meet our ongoing projects;

Optimized Customer Process: Apply technologies to simplify workflows, improve resource management, reduce waste, and provide real-time data and analysis, empowering customers to make quick and accurate decisions;

Commitment to Excellence: Contribute significantly to agribusiness by introducing effective solutions that set the state of the art in the monitoring system for stored grains.

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Acknowledgment

The authors would like to thank the support of the GRUPO CRIAR, especially **CRIAR Space Systems**, and **EMBRAPA**, which provided the resources to carry out this work up to the current stage.

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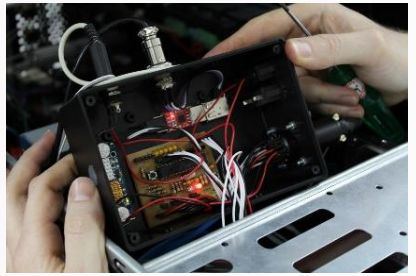
Company Overview

Founded in 2018, **CRIAR SPACE SYSTEMS** is a **GRUPO CRIAR** company designed to develop products and systems for the aerospace area, such as Automatic Directional Antennas (ADAs), CubeSats, and applications that enable monitoring through the data provided by these products.

GRUPO CRIAR has more than 30 years of experience in developing intelligent systems integrating software and hardware, applied to the areas of transit, transport, security, distance learning and more.

- ✓ High Technology
- ✓ Competence
- ✓ Committed team
- ✓ Transparency
- ✓ Support of Excellence



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Company Awards

- ✓ e-SILOBAG project was awarded at the event SPACEBR SHOW 2023 presenting innovative solutions for agribusiness and discussing about electronic monitoring of silo bags, quality and safety of stored grains;
- ✓ DATASAT project was awarded the 3rd place at the event SPACEBR SHOW 2022 by Amazon Web Services (AWS) and Brazilian Space Agency (AEB): Encourage entrepreneurship and disruption among companies in the space sector;
- ✓ DATASAT Project was included in the Annals of 72nd International Astronautical Congress (IAC 2021), presenting ADA Ground Station Network. Automatic Directional Antenna for Space Communications on Low Orbit;
- ✓ 3rd Place in the Innovation Challenge promoted by PARIS SPACE WEEK 2021;
- ✓ 2nd Place in the *"Desafio SERFA 2020"*, Symposium on Remote Sensing of Defense Applications, Brazil. Challenges: Intelligent integrative systems using drones.
- ✓ 2nd Place in the 71st International Astronautical Congress (IAC) 2019;
- ✓ Annals of the "II Congresso Aeroespacial Brasileiro" (CAB) 2019;
- ✓ Automatic Directional Antenna was awarded at the 2nd Forum of the Brazilian Space Industry 2018 as one of the best solutions of the event.

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